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AN ANALYSIS OF WIND SPEED VARIATIONS INSIDE AND OUTSIDE OF THE ATMOSPHERIC BOUNDARY LAYER DURING CONVECTIVE STORMS USING SODAR AND RADIOSONDE DATA

Iris ȚIȚINEANU[1],
Georgeta BANDOC[2], Mircea DEGERATU[3]

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Rezumat. *Lucrarea analizează variațiile vitezei medii ale vântului în interiorul stratului limită atmosferic și în troposfera liberă, bazându-se pe datele provenite din sondarea pe verticală a atmosferei utilizând date SODAR și din radiosondaje. Variațiile vitezei medii ale vântului din interiorul și din exteriorul stratului limită atmosferic au fost analizate utilizând date colectate în timpul avertizărilor de furtuni convective, dar și înainte și după 12 ore de la acestea. Rezultatele sunt importante în înțelegerea modului în care se comportă vântul în stratul limită atmosferic și în atmosfera liberă înainte, în timpul și după episoadele de furtuni convective.*

Abstract. *This paper analyzes the mean wind speed variations inside the atmospheric boundary layer and in the free troposphere based on data from vertical sounding of the atmosphere using SODAR and radiosonde data. The variation of the mean wind speed inside and outside of the atmospheric boundary layer were analyzed using data collected during warnings of convective storms, but also 12 hours before and after the alerts. The resulting data are important in understanding the way the wind behaves in the atmospheric boundary layer and the free troposphere before, during and after convective events.*

Keywords: wind, boundary layer, sodar, radiosonde

1. Introduction

The atmospheric boundary layer (ABL) represents that part of the inferior planetary layer of the atmosphere wherein the air movements are strongly influenced by the interaction with the surface of the Earth.[1]

In contrast to the free troposphere, which is located immediately above, the ABL is readily identified by its highly turbulent nature, which is driven by its constant interaction with the surface.[2]

[1] PhD (ABD), Faculty of Geography, University of Bucharest, Bucharest, Romania, (iris.titineanu@yahoo.de).
[2]Prof., Faculty of Geography, University of Bucharest, Bucharest, Romania, Academy of Romanian Scientists (geobandoc@yahoo.com).
[3]Prof. Eng., Technical University of Civil Engineering, Bucharest, Romania Academy of Romanian Scientists (mircea.degeratu@yahoo.com).

In order to identify and examine the properties of the ABL and of the free troposphere, good wind speed measurements are required. Measurements by remote sensing instruments such as Doppler SODAR, lidar, radar, and radiosondes offer advantages over point measurements as they yield wind information from different heights.[3][4][5]

The goal of this research is to describe the mean wind speed distribution inside the ABL and in the free troposhere in the area of Bucharest, Romania, during convective storms as well as 12 hours before and after, in order to understand the behavior of winds in the ABL and the free troposhere during convective storms.

2. Data and Methodology

The SODAR data for this study were collected from 2018 to 2021 with the METEK PCS.2000-64 monostatic Doppler Sodar located at the Henri Coandă International Airport. It was operated with a vertical resolution of 30 m, a first range gate (minimum height) of 40 m and a potential maximum range of 610 m. The zenith angle of the sound beams was set to 17° and the integration time to 10 min. [6]

The upper air sounding measurements were also collected from 2018 to 2021, with a Vaisala radiosonde deployed from the National Meteorological Administration's Bucharest Afumați Aerological Station twice daily, at 00 and 12 UTC.

Using the National Meteorology Administration's severe weather warnings archive, we identified the days and times of the code yellow and code orange alerts for severe thunderstorms during the summer months. The data recorded with the SODAR and radiosonde during the warnings of convective storms, but also 12 hours before and after the warnings were then extracted.

This data was then used to construct graphs in Microsoft Excel, in order to determine the vertical distribution of the mean wind speed inside and outside the ABL on days with weather warnings both of code yellow and code orange. This was meant to determine the mean wind speed distribution in the ABL and in the free atmosphere during the weather warnings but also 12 hours before and after the alerts.

3. Results

3.1. Vertical distribution of the mean U wind speed inside the ABL on days with code yellow warnings

A series of tests for the exploration of the atmospheric boundary layer using the SODAR equipment were conducted on days with yellow code warning for convective storms.

The tests consisted, first of all, in determining the vertical distribution of the local temporal average U wind speed in the ABL, on days with code yellow weather warnings.

The variations of the mean wind speed U as a function of height z with respect to the ground surface, determined with the SODAR equipment, were represented graphically in Fig.1.a. and 1.b.

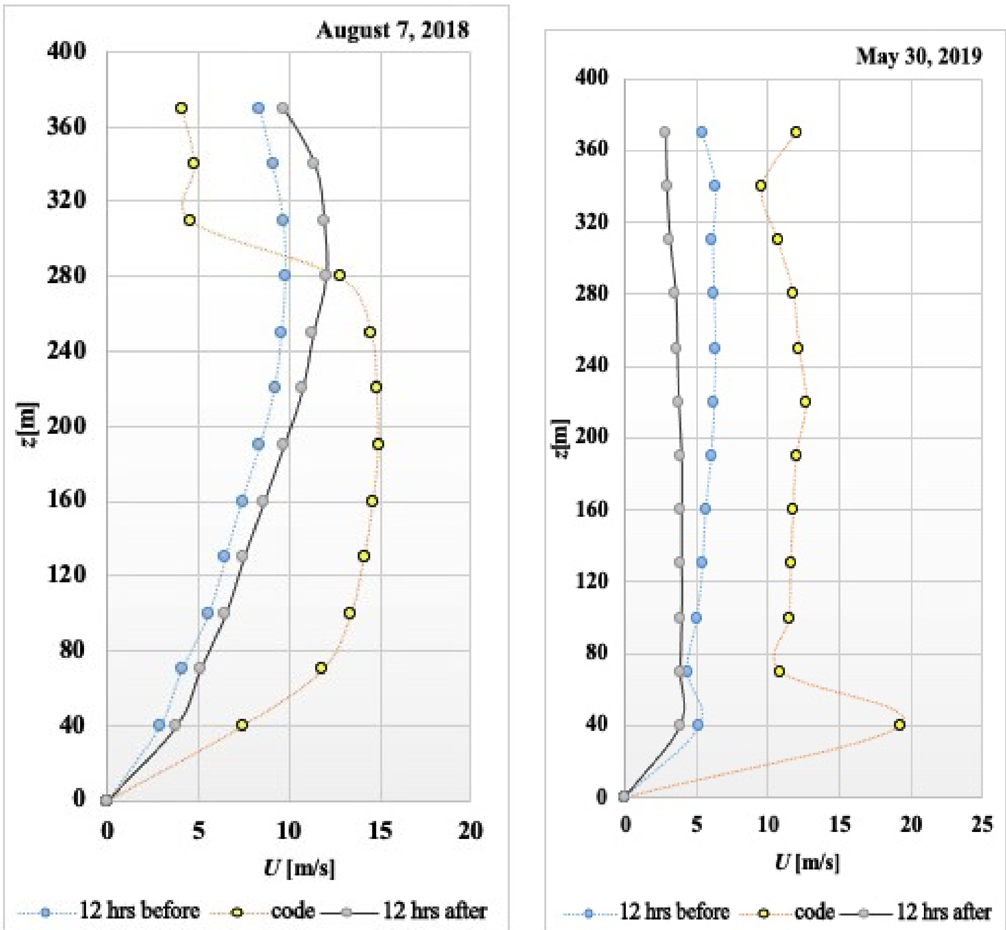

Fig. 1. Variation of wind speed U with height z in the ABL of the studied area, with code yellow.

a. SODAR testing, year 2018; b. SODAR testing, year 2019.

The analysis of the vertical variations of the mean wind speed in the ABL shows that speeds are generally higher during the code yellow weather warning compared to the mean speeds 12 hours before and after.

The mean speeds determined 12 hours after the alert generally decrease, but remain slightly higher than the speeds determined 12 hours before the issuing of the code yellow warning.

3.2. Vertical distribution of mean U wind speed inside the ABL on days with code orange warnings

A series of tests for the exploration of the atmospheric boundary layer using the SODAR equipment were also conducted on days with code orange warnings for convective storms. The tests consisted, first of all, in determining the vertical distribution of the local mean temporal speed of the U wind in the area of the Atmospheric Boundary Layer, during days with code orange warnings.

These tests were meant to determine the mean wind speed distribution in the ABL area, both during the code orange warning and 12 hours before and after the alert.

The variations of the mean wind speed U as a function of height z with respect to the ground surface, determined with the SODAR equipment, were represented graphically in Fig.2.a. and 2.b.

The analysis of these vertical variations of the mean U wind speed in the ABL shows that, in general, the speeds are higher during the orange code warning compared to the mean speeds before and after the warning. The average speeds determined 12 hours after the code orange alert generally decrease, but remain slightly higher than the speeds determined 12 hours before the issuing of the orange code warning.

3.3 Vertical distribution of mean U wind speed outside the ABL on days with code yellow warnings

A series of tests for the exploration of the free troposhere using upper air soundings were conducted on days with code yellow warnings for convective storms.

The tests consisted, first of all, in determining the vertical distribution of the local temporal average U wind speed in the ABL, on days with code yellow weather warnings.

The variations of the mean wind speed U as a function of height z with respect to the ground surface, determined with the radiosonde, were represented graphically in Fig. 3.a. and 3.b.

There are some differences between the three curves representing the vertical distribution of wind speed during the code yellow warning, 12 hours before and 12 hours after.

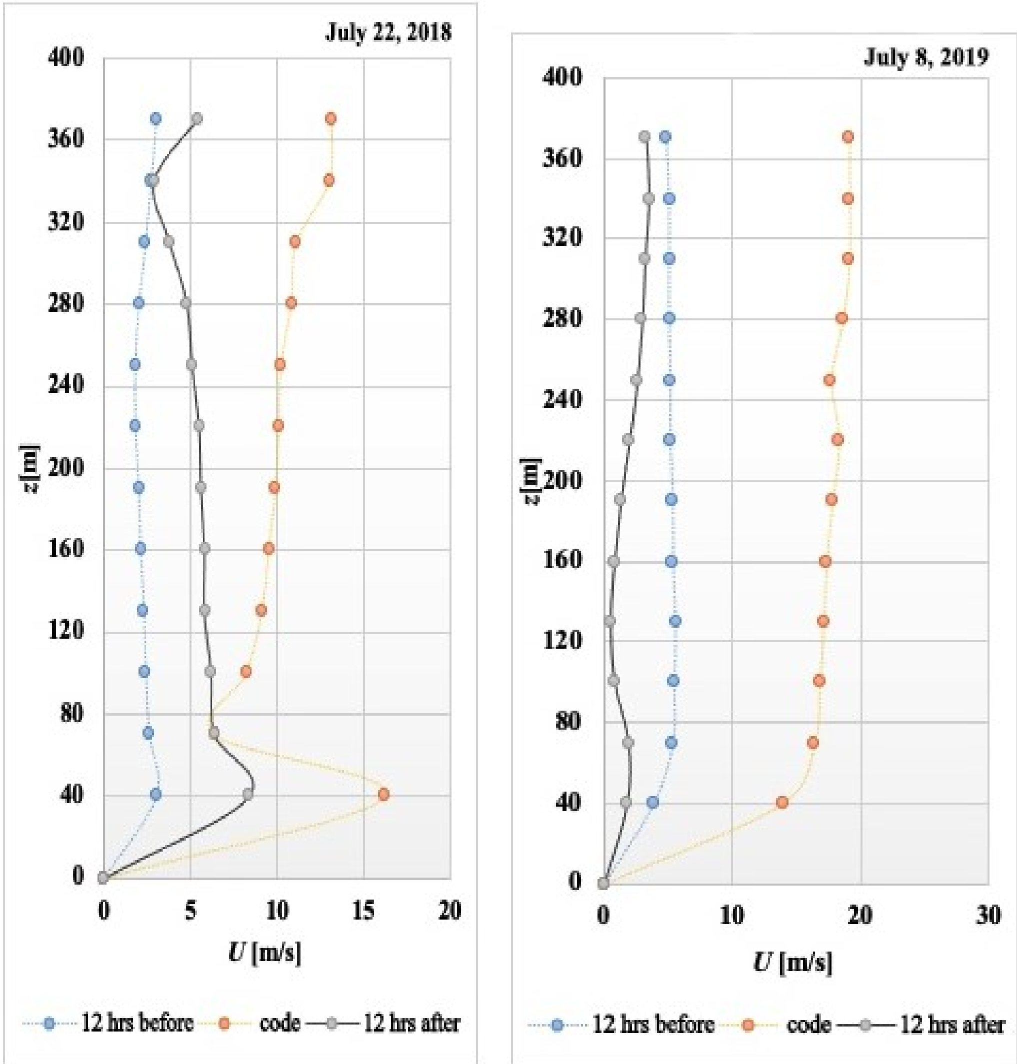

Fig. 2. Variation of wind speed U with height z in the ABL of the studied area, with code orange.

a. SODAR testing, year 2018; b. SODAR testing, year 2019.

In the lower part of the free troposphere, right above the ABL, the mean wind speeds are close to one another in value, sometimes even overlapping because of the mixing layer with strong turbulence alternating with the mixing layer with weak turbulence.

In the upper part of the troposphere, the mean wind speed values are close, but with visible differences, the speed during the code yellow alert being greater than

the speed outside the warning, due to the weaker influence of the ageostrophic wind.

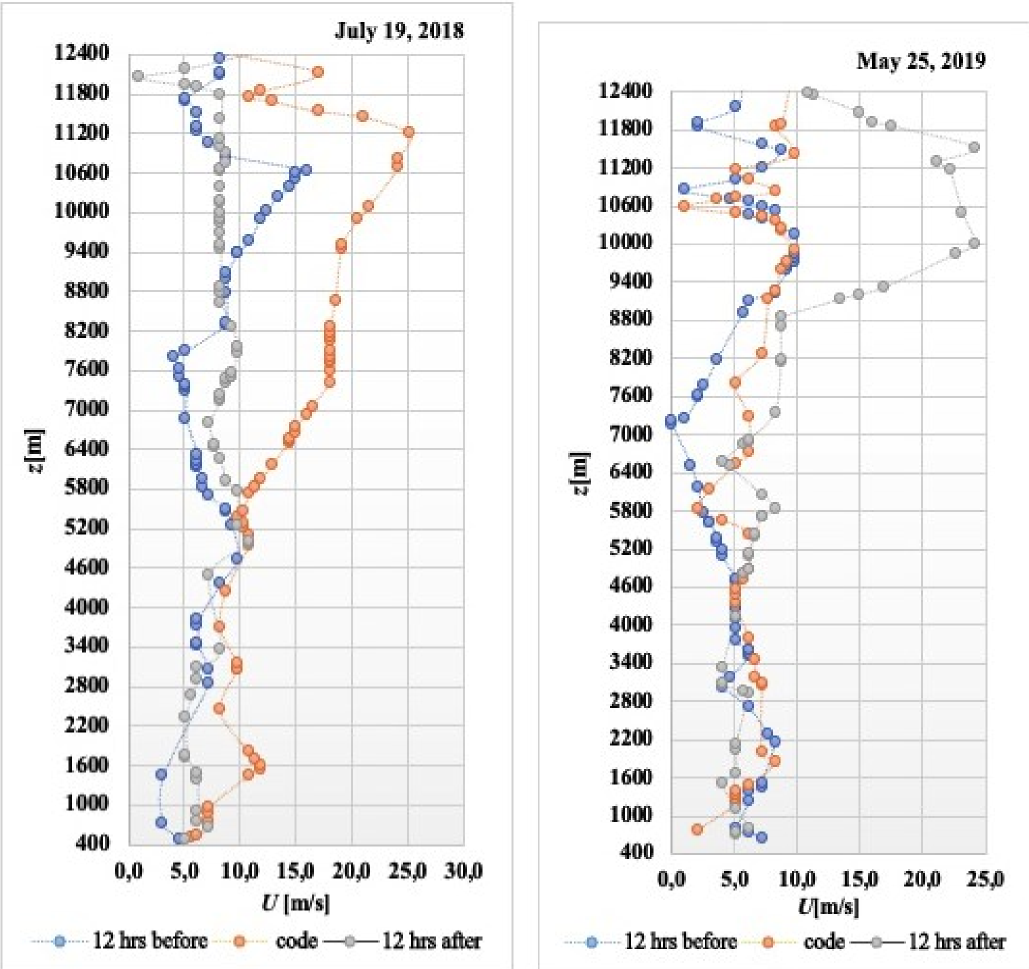

Fig. 3. Variation of wind speed U with height z outside the ABL of the studied area, with code yellow.

a. Radiosonde testing, year 2018; b. Radiosonde testing, year 2019.

3.4 Vertical distribution of mean U wind speed outside the ABL on days with code yellow warnings

A series of tests for the exploration of the free troposhere using upper air soundings were also conducted on days with orange yellow warning for convective storms.

The tests consisted, first of all, in determining the vertical distribution of the local temporal average U wind speed in the ABL, on days with orange code weather warnings.

The variations of the mean wind speed *U* as a function of height *z* with respect to the ground surface, determined with the radiosonde, were represented graphically in Fig. 4.a. and 4.b.

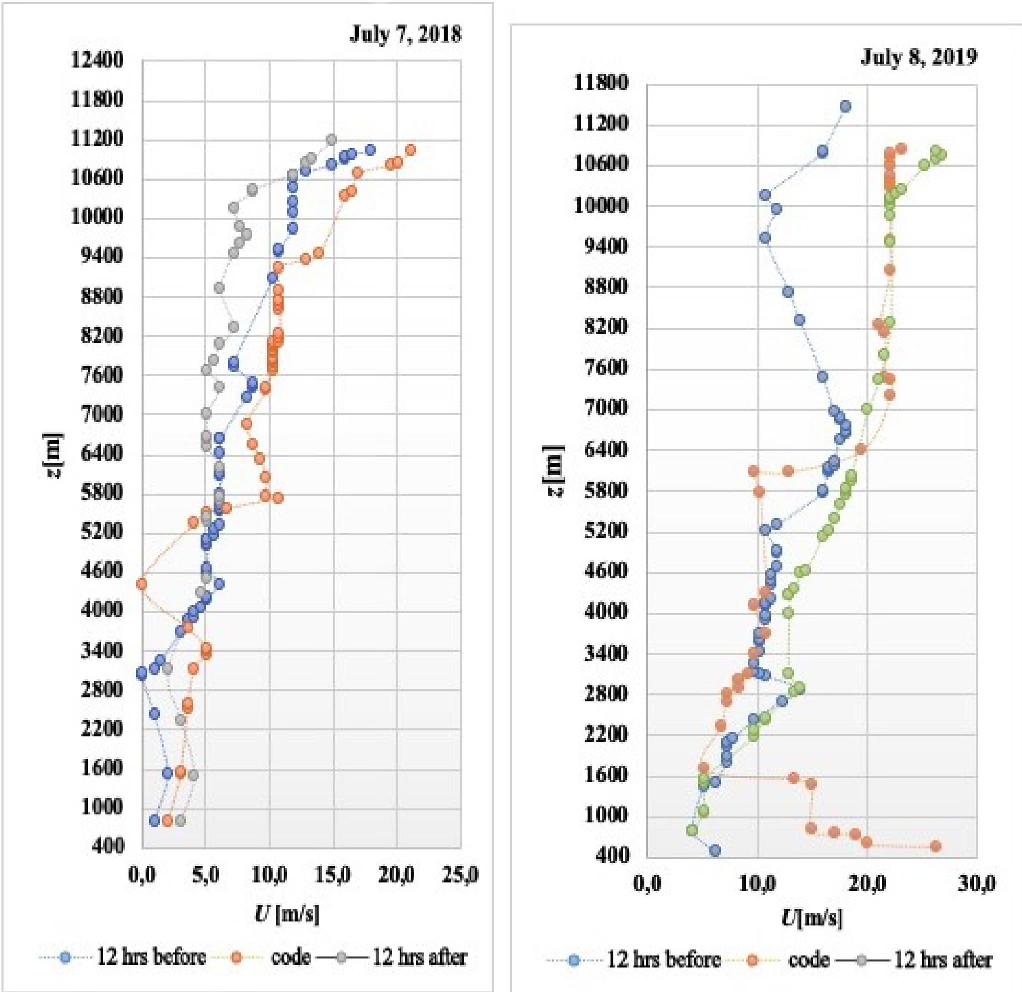

Fig. 1. Variation of wind speed U with height z outside the ABL of the studied area, with code orange.
a. Radiosonde testing, year 2018; **b.** Radiosonde testing, year 2019.

There are differences between the three curves representing the vertical distribution of wind speed during the code orange, 12 hours before and 12 hours after the warning.

In the lower part of the free troposphere, right above the ABL, the mean wind speeds are close to one another in values, even overlapping at times because of the mixing layer with strong turbulence alternating with the mixing layer with weak turbulence.

In the upper part of the troposphere, the mean wind speed values are still close in value, but there are visible differences, the speed during code orange being greater than the speed outside the warning, due to the weaker influence of the ageostrophic wind.

Conclusions

The analysis of the mean wind speeds in the ABL shows that, in general, the mean wind speeds are higher during the weather warnings compared to the mean speeds before and after.

The mean speeds determined 12 hours after the warning generally decrease, but remain slightly higher than the speeds determined 12 hours before the severe weather event.

The analysis of the variations of wind speed in the free troposphere, also show some differences between the three curves representing the vertical distribution of wind speed during the code orange, 12 hours before and 12 hours after the warning.

In the lower part of the free troposphere, right above the ABL, the mean wind speeds are close to one another in value, even overlapping at times, because of the mixing layer with strong turbulence alternating with the mixing layer with weak turbulence.

In the upper part of the troposphere, the mean wind speed values are still close in value, but there are visible differences, the speed during the severe weather warnings being greater than the speed before and after the warnings, due to the weaker influence of the ageostrophic wind.

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Abbreviations

ABL - atmospheric boundary layer.

R E F E R E N C E S

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